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Case Study – Denmark

Sustainable Agriculture and Soil Conservation (SoCo Project)

Preben Olsen,
Alex Dubgaard

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The project 'Sustainable Agriculture and Soil Conservation (SoCo)' is a pilot project commissioned by the Directorate-General for Agriculture and Rural Development, in response to the request of the European Parliament (Administrative Arrangement AGRI-2007-336).

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Preface

Agriculture occupies a substantial proportion of European land, and consequently plays an important role in maintaining natural resources and cultural landscapes, a precondition for other human activities in rural areas. Unsustainable farming practices and land use, including mismanaged intensification and land abandonment, have an adverse impact on natural resources. Having recognised the environmental challenges of agricultural land use, in 2007 the European Parliament requested the European Commission to carry out a pilot project on 'Sustainable Agriculture and Soil Conservation through simplified cultivation techniques' (SoCo). The project originated from close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). The JRC's Institute for Prospective Technological Studies (IPTS) coordinated the study and implemented it in collaboration with the Institute for Environment and Sustainability (IES). The overall **objectives of the SoCo project** are:

(i) to improve the understanding of soil conservation practices in agriculture and their links with other environmental objectives;

(ii) to analyse how farmers can be encouraged, through appropriate policy measures, to adopt soil conservation practices; and

(iii) to make this information available to relevant stakeholders and policy makers EU-wide.

In order to reach a sufficiently detailed level of analysis and to respond to the diversity of European regions, a case study approach was applied. Ten case studies were carried out in Belgium, Bulgaria, the Czech Republic, Denmark, France, Germany, Greece, Italy, Spain and the United Kingdom between spring and summer 2008. The case studies cover:

- a screening of farming practices that address soil conservation processes (soil erosion, soil compaction, loss of soil organic matter, contamination, etc.); the extent of their application under the local agricultural and environmental conditions; their potential effect on soil conservation; and their economic aspects (in the context of overall farm management);
- an in-depth analysis of the design and implementation of agri-environmental measures under the rural development policy and other relevant policy measures or instruments for soil conservation;
- examination of the link with other related environmental objectives (quality of water, biodiversity and air, climate change adaptation and mitigation, etc.).

The results of the case studies were elaborated and fine-tuned through discussions at five stakeholder workshops (June to September 2008), which aimed to interrogate the case study findings in a broader geographical context. While the results of case studies are rooted in the specificities of a given locality, the combined approach allowed a series of broader conclusions to be drawn. The selection of case study areas was designed to capture differences in soil degradation processes, soil types, climatic conditions, farm structures and farming practices, institutional settings and policy priorities. A harmonised methodological approach was pursued in order to gather insights from a range of contrasting conditions over a geographically diverse area. The case studies were carried out by local experts to reflect the specificities of the selected case studies.

This Technical Note is part of a series of ten Technical Notes referring to the single case studies of the SoCo project. A summary of the findings of all ten case studies and the final conclusions of the SoCo project can be found in the **Final report on the project 'Sustainable Agriculture and Soil Conservation (SoCo)'**, a JRC Scientific and Technical Report (EUR 23820 EN – 2009). More information on the overall SoCo project can be found under http://soco.jrc.ec.europa.eu.

BE - Belgium	**West-Vlaanderen** (Flanders)
BG - Bulgaria	**Belozem** (Rakovski)
CZ - Czech Republic	**Svratka river basin** (South Moravia and Vysočina Highlands)
DE - Germany	**Uckermark** (Brandenburg)
DK - Denmark	**Bjerringbro and Hvorslev** (Viborg and Favrskov)
ES - Spain	**Guadalentín basin** (Murcia)
FR - France	**Midi-Pyrénées**
GR - Greece	**Rodópi** (Anatoliki Makedonia, Thraki)
IT - Italy	**Marche**
UK - United Kingdom	**Axe and Parrett catchments** (Somerset, Devon)

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Acronyms

EU	European Union
ha	hectare
NGO	Non Governmental Organisation
P	phosphorus
UAA	Utilised Agriculture Area

1 Introduction to the case study area

1.1 Spatial and natural characteristics

The Danish case study area consists of the two municipalities Bjerringbro and Hvorslev, being located in the central part of the peninsula of Jutland, approximately 30 km southwest of the city of Randers. In 2007 the municipality of Bjerringbro was merged with 5 other municipalities forming a new municipality named Viborg and Hvorslev merged with 3 others forming a new municipality named Favrskov. Numerous research projects, involving a variety of research disciplines such as history, sociology, archaeology, ecology, biology, agronomy, hydrology and geology have been conducted in the Bjerringbro/Hvorslev study area, dealing with past, present or future land use (see: http://www1.sdu.dk/Hum/ForandLand/index.html and http://web.agrsci.dk/djfpublikation/djfpdf/djfma110.pdf).

For the 30-year-period 1961-1990 the average annual precipitation within the study area was around 800 mm and the average yearly temperature 7.6º C. The prevailing wind direction in the area is western.

The geological setting of the area was formed during the Weichselian Glaciation. The glaciers came to a stop, just a few kilometres to the West and North of the study area. This is the reason for the dividing line, separating the poor, sandy soils in the West, (that had not been covered by ice) from more fertile soils being mostly sandy loams and finer textured soils covering the Eastern part of the study area.

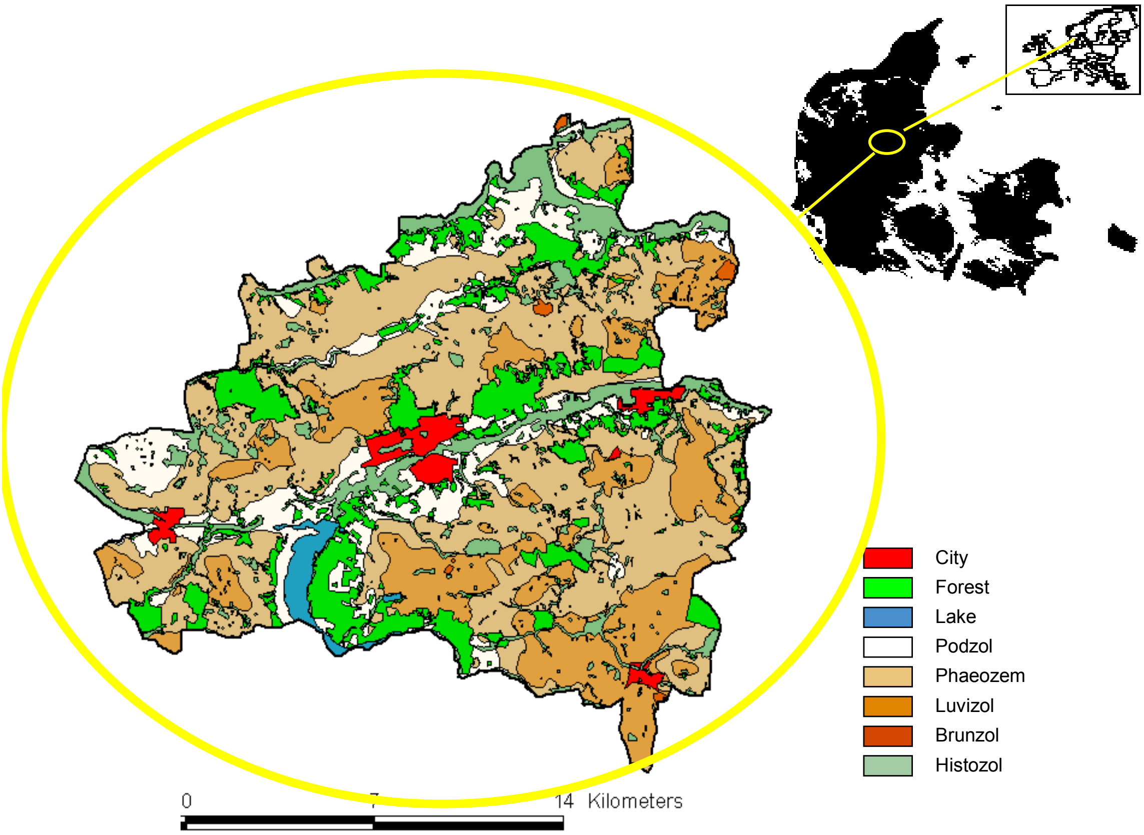
Several geological features such as pitting due to dead ice formation, smaller, terminal moraines in association with melt water plains, moraine plateaus as well as erosion valleys were formed by melt water. In general, the landscape is characterised by a moraine plateau with an average altitude of 50-60 m above sea level, in some areas reaching an altitude of 100 m.

Two valleys, formed by the rivers Nørreå and Gudenå, separate the moraine plateau. From the plateau several, minor erosion valleys, formed at the end of the glaciation some 10,000 years ago, feed into the two valleys.

Very accurate soil type information is available for the area as intensive measurements within the area has formed the basis for a new methodology for soil classification in Denmark. The soil survey included a detailed mapping at field level, using the electromagnetic sensor, EM38.

A high-resolution digital elevation model, obtained by use of laser scanning, is available for the study area. The original scanning has a horizontal resolution of 20 cm in vertical of 15 cm.

Figure 1: Soil types and location of the Danish study area



Source: Torp, 2004

Based on a detailed soil mapping of the Utilised Agricultural Area (UAA) within the Bjerringbro/Hvorslev area the three major soil types used for agriculture were found to be Podzols covering around 18 % of the UAA, Phaeozems makes up around 44 % and finally, Luvizols are covering some 20 % of the area. These three types of soils are at the same time the most common in Denmark where their distribution is roughly the same. Examples for the texture of the 3 soil types are given in the Tables 1-3.

Table 1: Example of a podzol

Horison			Clay	Silt		Fine sand	Medium sand		Coarse sand
				Fine	Coarse		Fine	Coarse	
Name	Depth, cm	Organic matter	< 2 µm	2-20 µm	20-63 µm	63-125 µm	125-200 µm	200-500 µm	500-2000 µm
Ap	0-18	1,1	5	2	2	4	8	59	19
Bs	18-29	1,4	6	3	6	0	4	58	20
2Bs1	29-63	0,2	3	1	1	0	1	63	31
2Bs2	63-120	0,1	2	1	1	0	1	78	17
3C	120-150	0,1	2	1	1	0	2	48	46

Table 2: Example of a phaeozem

Horison		Organic matter	Clay	Silt		Fine sand	Medium sand		Coarse sand
				Fine	Coarse		Fine	Coarse	
Name	Depth, cm		< 2 µm	2-20 µm	20-63 µm	63-125 µm	125-200 µm	200-500 µm	500-2000 µm
A1p	0-40	2,0	9	13	18	17	13	19	8
A2	40-60	0,5	18	14	16	16	15	15	6
B1t	60-130	0,2	19	11	13	16	14	20	7
BC	130-	0,1	18	12	16	16	14	19	7

Table 3: Example of a luvizol

Horison		Organic matter	Clay	Silt		Fine sand	Medium sand		Coarse sand
				Fine	Coarse		Fine	Coarse	
Name	Depth, cm		< 2 µm	2-20 µm	20-63 µm	63-125 µm	125-200 µm	200-500 µm	500-2000 µm
A1p	0-35	2,0	25	14	12	12	11	17	8
A2	35-45	0,6	35	11	11	9	8	17	8
B2t	45-90	0,3	35	12	10	10	10	16	7
BC	90-	0,2	20	9	13	12	14	24	9

1.2 Main soil degradation issues

Loss of soil due to erosion by water on sloping fields is less a problem than the loss of phosphorus either dissolved in the flowing water or attached to fine soil particles eroded by the surface runoff. In particular, at the upper end of the stream network, water quality can be endangered (Kronvang et al., 2000), as the distance between streams and eroded fields will be shorter than in the large river valleys. Loss of nutrients may cause eutrophication of streams as well as lakes.

The risk of water erosion depends on the type of soil, land use as well as amount, intensity and timing of precipitation. Problems may in particular arise on fields ploughed across contour lines; sown with winter cereals; planted with Christmas trees or having layers impeding the water infiltration e.g. plough pans and compacted layers. Occasional heavy rainstorms, prolonged and enduring rain as well as snowmelt may trigger erosion (Jacobsen et al., 2000).

Erosion by wind can occasionally transport large amounts of soils. However, new, efficient shelterbelts and winter crops have reduced the problems. Enlargement of fields may have the opposite effect, as distances between shelterbelts will increase.

The use of heavy machinery in the fields, in particular when the soil moisture is high, can cause problems of soil compaction, especially in the loamier parts of the case study area. As farm size has increased so has machinery and thereby the load and force applied to the soil. In order to reduce their costs of production many farms do not have all of the necessary machinery for cultivating their fields. Some have to rely on private contractors, who may have large machinery able to work the fields at inappropriate time as seen from a soil conservation point of view i.e. when the soil is moist and sensitive to permanent damage.

In general, organic matter content of arable, mineral soils has declined due to changes in crop rotation (more cereals and less grass and perennial crops); removal of straw for heating purposes; commercial fertiliser replacing manure. The rising demand for bio-fuels may further increase the organic matter depletion.

The actual erosion has been recorded on some of the fields within the area between 1994 and 1999. These studies were part of a larger research project on erosion throughout Denmark, aimed at constructing a model for prediction of erosion occurrence (Djurhuus et al., in preparation). There has been no specific study of soil compaction or organic matter depletion within the study area. There is however no reason to believe that these problems should be any different compared to the situation throughout Denmark. Their possible specific negative effect on soil fertility and yields may not be assessed directly, as the other parameters may interact, e.g. changes in weather and N-fertilisation.

Figure 2 shows potential water erosion and deposition within the study area calculated by use of the Belgium water erosion model called Watem (http://www.kuleuven.ac.be/-facdep/geo/fgk/leg/pages/downloads/watem.htm).

The data basis for the calculation was a new digital elevation model with a resolution of 10*10 metres; a K-factor map based on the soil map of Denmark (Greve et al., 2008) using a pedotransferfunction (Renard et al., 1996); an R factor was based on (Leek and Olsen, 2000).

Figure 2: Potential soil erosion risk within the Bjerringbro/Hvorslev study area

Source: Goswin Heckrath, personal communication

2 Methodology

Semi structured interviews with farmers based on SoCo-CS Questionnaire 2 (Q 2), were conducted face-to-face with four farmers at their farms. All farmers owned their farm and all of them rented land from neighbours. All four were trained farmers having been to agricultural schools and working at other farms during their training as farmers.

Only threats relevant for the case study area were included, leaving out salinisation and acidification. As there are no policies in Denmark aimed specifically at the protection of soil, section C and D of Q2 were not dealt with in detail.

Soil experts were consulted informally, i.e. no questionnaires were used.

To investigate the processes behind policy design and implementation of soil related policies in Denmark interviews were conducted with officials from the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment. SoCo-CS Questionnaire 3 was used for these interviews. In addition a representative from the Ecological Council (an NGO) was interviewed using SoCo-CS Questionnaire 4.

3 Perception of soil degradation in the case study area

3.1 Soil degradation problems

Based on interviews with experts three main degradation processes were identified and their causes and impact are listed in Table 4.

Table 4: Experts' assessment on soil degradation processes in the DK case study catchments

Soil degradation process	Causes	Impact
Water erosion: The detachment and transport of nutrients (dissolved or attached to fine soil material) from fields to fresh water bodies	• Rain on surface not protected by e.g. a crop • Snowmelt or rain falling on frozen soil • Slope length and gradient • Inappropriate cultivation techniques crushing soil aggregates, increasing the soils susceptibility of sealing/slacking • Concentrated flow • Tramlines and other linear features	• Loss of particulate or dissolved P from fields impairs the quality of water bodies
Decline in organic matter: Organic matter is essential for soil aggregate formation and stability and provision of nutrients	• Mineralisation due to frequent soil tillage • Removal of biomass for energy production e.g. straw from cereals • Use of inorganic rather than organic fertilisers	• Structural degradation • Soil sealing/crusting • Reduced infiltration • Increased vulnerability to compaction and water erosion

Compaction: By reducing the porosity of a soil its ability to sustain crop growth is restricted; access to water, nutrients and air diminishes. Deep soil compaction almost irreversible as neither tillage nor biology can relieve the damage	• Working or trafficking a soil when to wet to sustain the weight of the farming machinery: spreading of slurry in spring; harvest of maize and root crops in autumn	• Reduces infiltration and water holding capacity of the soil • Impermeable, compacted layers reduce deep infiltration and promote water erosion through surface or interflow of water. • Increased risk of crop failure due to insufficient water supply as root development becomes restricted • Deep soil compaction almost irreversible as neither tillage nor biology can effectively relieve the damage

Farmers' assessment of soil degradation problems

Generally, the farmers saw the threat of soil compaction as being related to the heavy traffic when spreading slurry in early spring. Problems were not related to one crop in particular, but to the timing of slurry spreading in relation to the wetness of the soil. Compaction could arise in crops sown in the spring as well as in autumn. The farmers had all perceived the problem, and had taken action e.g. purchased their own spreading equipment, enabling them to spread at the most appropriate time, or using contractors with special spreading equipment. As they had realised the problem and acted accordingly, the threat was seen as being high though not a problem to their soil any more.

Farmers saw problems of wind and water erosion as being scarce. Wind erosion had been seen on sandy soils in the past. However, the increase in winter green fields had solved the issue.

Risks exist, however, in particular in spring where traditional seedbed preparation may dry out the topsoil. Strong winds in spring may cause wind erosion before a spring sown crop can provide protection of the soil surface.

Farmers had noticed rare instances of water erosion in the autumn on tilled black soil or on newly sown winter crops of e.g. winter rape or winter wheat.

None of the farmers considered water erosion a significant problem for their land. Three of the farmers had observed sporadic water erosion on fields in the study area, not on their own fields, however. Two of them related this to precipitation events in the autumn shortly after sowing of a crop of winter wheat or winter rape. One farmer had noticed that on his neighbour's winter rape field, sown after traditional ploughing, situated just next to his own field of winter rape on similar soil. However, as he himself used no-plough tillage erosion rills where absent on his own field. This he ascribed to the reduced tillage system. Another farmer had in the past observed erosion during the end of a winter when snow melted on frozen soil.

Table 5: Main soil degradation issues

Case study area Bjerringbro/Hvorslev (DK)	Main soil degradation issues		
	Soil erosion (wind and water)	Decline in organic matter	Soil compaction
Farmers (N=4) view upon threats on own field	1	1	4
Farmers (N=4) view upon threats in the overall area	1	1	4
Experts (N=2) view upon threats in Bjerringbro and Hvorslev (DK)	2	2	4

Note: Main soil conservation issues in the case study areas on a severity scale from 1-5. Figures are given as average of the interviewed farmers and experts, respectively. Information from farmers is obtained by semi-structured interviews, using Q. 2. Soil experts were questioned in an informal way, not using any of the questionnaires. 1= no problem and 5=severe problem.

Wind erosion had been observed by all farmers on sandy soils in the past. Since the introduction of winter green fields, originally aimed at reducing nitrate leaching to ground water, the problem had disappeared almost totally. All farmers rated this at the value of 1.

Organic matter decline, due to removal of straw for power production and heat production was regarded a potential problem for soil productivity and stability by 1 farmer. However none of the 4 farmers considered reduced organic matter of the soil as a problem in a foreseeable future.

None of the farmers had knowledge on the carbon balance of their soils.

Diffuse contamination with nitrate or pesticides was not considered a problem. All farmers were obliged to have catch crops on a large part of their fields. They were all eager in avoiding the leaching of nitrogen as there are restrictions on their buying of commercial fertilisers as well as regulations of the use of manure. In particular, at present 70 % of the nitrogen in manures have to go into their fertilisation accounting schemes.

All four farmers considered soil compaction by heavy machinery the most serious threat to the soil.

Retention capacity of the soils was not considered as a problem. One farmer doing no-plough tillage did, however, state that his soils had increased their retention capacity. He had no measurements but had realised that his fields appeared greener than those fields of his neighbours that had been ploughed. This was in particular visible in spring-sown barley during dry periods in spring or beginning of the summer.

Salinisation is not an issue in Denmark due to the ample rain.

Against acidification 3 of the 4 farmers applied lime on a regular basis (~ every 5 years) – whereas the one using no-plough tillage stated that the application of pig manure kept the pH of his soil in the higher end of the needed.

Overall all farmers rated the above listed degradation to 1 on the scale of 5. The only threat rated as 2 was that of soil compaction. That was the case for both the study area as a whole as well as on their individual farms.

Experts' perception of soil degradation problems

Soil degradation in the case study area is predominantly affected by the farming systems and the agricultural management practices as up to 93 % in the Danish case study is used for agricultural purposes. Soil degradation may eventually be subject to policy intervention, but at present there exists no specific policy nationally or locally aimed specifically at the protection of the soil resource. However, rules and regulations aimed at solving other environmental problems have had positive side effects, as the case of winter green fields aimed at reducing the leaching of nitrate had impacted problems of wind erosion. Another less beneficial effect of particularly winter wheat has, according to the view of experts caused more water erosion. Restriction on the spreading of manure to spring or the main growing season has reduced nitrate leaching but at the same time increased the risk of compaction.

Most, if not all of the major farming systems and management practices pertinent in Denmark, may be found in the case study area. Farming systems include rotational cropping systems with intensive fertiliser input and the use of heavy machinery. As it can be seen in Table 5 there is almost consensus among experts and farmers regarding the importance of the threats of degradation where compaction of the soil is identified as the major problem.

Generally Danish experts see soil erosion (by water) as less of a problem, when it comes to the amounts of soil being lost. However, they stress that erosion may cause pollution of inland waters particularly with phosphorus. Despite a large effort in cleaning municipal sewage effluents from phosphorus streams and lakes are still affected by P. There is an agreement among experts that this phosphorus originates from farmland – either by surface flow processes or through drainage systems. At present a P-index system is being developed aimed at pinpointing high risk areas of P loss to the aquatics.

Decline in organic matter is seen as a threat at the same level as erosion, particularly where continuous cereal production is the case particularly where the straw is removed for production of heat and electricity. In the long run problems of organic matter decrease may increase both the problems of erosion and compaction, as soil organic matter is essential for e.g. soil structure, soil aggregate stability and water holding capacity.

3.2 Trends in soil degradation and consequences

The trends in soil degradation problems as perceived by the interviewed farmers are shown in Table 6. Water erosion was scarcely observed as a soil degradation problem in the case study area. When farmers observed erosion it was just small rills. Except for one, none of the farmers had recollections of any serious, recent water erosion events. Another farmer recalled an incident from his childhood, when massive erosion had happened in the autumn on a harrowed, black soil. There they had to fill a gully with several truckloads of soil.

When water erosion happened today it was due to the climatic conditions in the autumn, rain falling on newly sown fields or in connection with the thawing of snow on frozen soils.

The farmers said that green fields during the wintertime as well as the use of catch crops had impacted on the risk of wind erosion, now being virtually absent.

As the farmers had all realised the threat of compaction and taken action accordingly, risks of compaction had been reduced.

Although the interviewed farmers did not see water erosion as a problem, soil researchers in Denmark generally told that the increased winter cereal production has led to higher rill erosion risk by water in autumn and winter. Rills are, depending on the climate, found in the tramlines and between seed rows, in particular where soils have been flattened and the aggregates crushed during the tillage operation. Experts hold that the frequently used procedure, where one tractor is doing the ploughing and shortly after (within ½ hour or so) another tractor sows the crop, using a rotor harrow, may aggravate the problem as soil aggregates are destroyed and the surface flattened/levelled leaving the surface practically without any water storage capacity, prone to crusting and susceptible to surface runoff.

Table 6: Trends in soil degradation in the case study Bjerringbro/Hvorslev

Soil degradation problem	farm 1	farm 2	farm 3	farm 4
Soil erosion (water)	0	0	0	0
Soil erosion (wind)	2	2	2	2
Decline in organic matter	2	1	1	1
Carbon balance	n.s	n.s	n.s	n.s
Diffuse contamination	1	1	1	1
Compaction	2	2	0	0
Salinisation	n.s.	n.s.	n.s.	n.s.
Acidification	n.s.	n.s.	n.s.	n.s.
Retention capacity	2	2	0	0
Off-site damages	n.s.	n.s.	n.s.	n.s.

Note: The numbers indicate the trend of soil degradation problems reported by farmers (n = 4) in response to Questionnaire 2 with a scale between -5 and +5; with the level being 5 = large positive change to 1 = small positive change and 0 = no change. n. s. = not specified

4 Farming practices and soil conservation measures

4.1 Farming practices and their effects on soil

The study area covers a total of 33,000 ha. The area has a population of 20,000 inhabitants of which 6,500 are living in the countryside (Höll et al., 2002). The Utilised Agricultural Area (UAA) is 21,225 out of which 19,740 ha (93 %) is arable and the remaining 1,485 ha permanent grasslands (7 %). Forests cover 6,600 ha of the study, area. The remaining 5,175 ha are used for infrastructure and cities.

In Table 7 land use and farming practice are shown. Indoor pig production is the dominant form of farms. Farms specialised in crop husbandry are second, whereas cattle, in particular dairy, ranks third. A large number of small hobby farms are found in the area. This reflects the general structural development within the Danish agriculture over the last decades towards fever but larger farms.

Table 7: Farm practices and farm types in Bjerringbro/Hvorslev municipalities in 2006

		Farming practice		Type of farm					
	Total	Conven-tional	Organic	Cattle	Pigs	Mixed animals	Plant	Hobby	Unclas-sifiable
Farms	703	666	37	76	87	15	64	421	40
Cultivated, ha	21.225	19.772	1.453	4301	7222	300	4626	3346	1431
Cultivated organic, ha	1.450	0	1.450	577	0	300	396	177	0
Animal units	24.185	23.314	871	6211	13076	169	569	873	3287
Animal units, pigs	15.169	15.157	11	158	13035	8	152	237	1579
Animal units, cattle	8.820	7.990	830	6050	30	116	413	555	1656
Animal units, dairy cattle	6.722	6.034	688	5426	0	0	0	28	1267
Animal units, beef cattle	2.070	1.928	142	624	30	116	401	512	389
Animal units, poultry	24	24	0	0	0	24	0	0	0

Source: IACS (Integrated Administrative and Control Systems)

All cultivated land within the area is privately owned. Many of the larger, animal farms rent land. In order to apply with the regulations on stocking densities they need to have sufficient land for the disposal of manure. Owners of land are generally obliged to live on their farm.

In 2006 the major use of the utilised agricultural area was winter cereals (37 %), spring cereals (20 %), winter rape (6 %), set aside (6 %), grass in rotation 11 %, permanent grassland (7 %).

Due to the precipitation being 800 mm per year, there will normally be no need for irrigation. Podzols may occasionally have a need, in particular when used for grass and green fodder, potatoes or vegetable crops. However, irrigation is highly regulated and farmers need permission from the municipality, which is not easily obtainable. There is no information on the actual size of the irrigated area. Likewise, no information on the size of drained land in the area is available.

The typical cropping systems, their characteristics and the estimation of impacts on soil degradation problems are compiled in Table 8 at the end of this section. Overall, farming is regulated by legislation e.g. restrictions on the use of fertilisers and pesticides; obligatory catch crops and winter green fields; maximum stocking densities. Traditional, the large majority of farmers uses ploughing be they conventional or organic. Besides economic and personal considerations, demography may exert an influence whether to change tillage practice or not. For instance, one farmer, in the beginning of his 60'ies, said that he would stick to the ploughing system until his retirement. Starting to use reduced tillage would require new and costly tillage implements and further engaging in a learning process, for which he had neither the will nor the time.

Another farmer that had been using no-plough tillage since 2000 had started doing so for the challenge of it. He said he saved time whereas cost of fuel and pesticides was similar to when using a plough. He had seen beneficial effects on his land regarding water holding capacity and drainage. However, the reason for using no-plough was not environmental concerns but economic reasons as well as convenience.

Another farmer had used no-plough tillage for a 4-year-period, sharing machinery with a neighbour, but stopped 3 years ago. One reason being that his farm was growing in size whereas that of the neighbour did not. The neighbour took over the machinery. Further, he was beginning to suffer from problems with grass weeds as well as with Fusarium fungi, affecting the productivity of his sows. Fusarium, he said, acted on the sows much like birth control pills do on women, reducing the numbers of pregnancies. And further, having that many animals, the use of no-plough tillage had become a stress factor. "You could have a good crop when using the ploughing system, even when your timing of the tillage was not all that well. A ploughing system", he said, "was more forgiving".

An organic farmer noticed that there could occasionally be water runoff when he was taking in new land for organic cultivation (e.g. buying new land). He had observed that after approx. 5 years surface water flow was no longer seen between the raised beds used for the cultivation of carrots. He ascribed this to his large area of grass/clover favouring earth worms (increased infiltration). Further, he used very large amounts of straw (approx. 60-70 tons of straw/ha) for covering carrots in the fields during the wintertime. The carrots were not harvested until shortly before they were sold.

No matter what kind of a tillage system is used by the farmers, all of them used either twin or wide low pressure tires. They all had observed the importance of heavy traffic in inducing compaction when the soil was moist, in particular in the spring when applying slurry.

Consequently, 3 of the 4 farmers now own their slurry spreading/incorporating equipment, whereas one, near the age of retirement, hired a contractor using a Vredo spreader. This could drive in dog walk-position – meaning that each of its wheels drove in separate tracks – and thereby minimising the risk of compacting to the soil.

The main soil degradation problem seen by soil experts and farmers in the Danish case study area is soil compaction. The interview farmers had all responded accordingly. For environmental reasons spreading of manures during autumn is nearly totally prohibited, the exceptions being minor amounts of manure before sowing of winter rape as well as on established grass fields. This has had a beneficial effect on the quality of ground and surface waters regarding especially nitrate. A less beneficial effect of the ban has been the increased risk of soil compaction.

As a result of the legislation aimed at reducing loss of nitrogen, farmers are obliged to have a green cover on large parts of their acreage during the winter. This has led to a large increase in the cultivation of winter wheat. Some Danish experts argue that the expansion in winter wheat has had very little influence in reducing nitrate leaching. It has however caused higher risk of water erosion both in tramlines used when spraying pesticides during autumn and from large parts of the fields themselves as the intense tillage of the soil has reduced the surface water storage capacity and thereby the risk of surface runoff and eventually erosion. Winter green cover has on the other hand taken care of problems of wind erosion in the area, even though many shelterbelts were removed when farms and fields were enlarged to be more efficient. The increase in farm and field size has on the other hand increased the size of the machinery used, and thereby the load exerted on the soil.

Besides heavy machinery animals trampling the soil may cause soil compaction. This issue was however raised by neither the farmers nor soil experts.

Detailed description of contents of farmer interviews

The detailed contents of farmer interviews are recorded below for more detailed reference to the each farmer’s particular situation. However, all relevant information from the interviews has been included in the previous sections.

Farmer 1

This farmer had chosen to become an organic farmer for animal welfare reasons. Having worked at a conventional dairy farm in the late 80ies with many visitors, he was posed many questions regarding the handling of the animals and regarding animal welfare. This had influenced his decision to become an organic farmer when he bought his own farm.

Runoff of water and sediment are occasionally seen from fields to roads within the neighbourhood. When taking new land for organic cultivations (buying/leasing) it is observed that approx. 5 years will pass before surface water flow is no longer seen between the raised beds used for the cultivation of carrots. The farmer does not see any erosion on his land ascribing that to the large acreage of grass/clover favouring the earth worms. Further, he used very large amounts of straw for covering carrots in the fields during the winter time, as carrots are not harvested until shortly before they are to be sold (ca. 60-70 tons of straw/ha).

Wind erosion is no longer a problem as most of the fields now having a soil cover during autumn and winter. To avoid compaction of the soil by heavy machinery, particularly in spring when spreading slurry, the farmer has now purchased his own equipment. The problem with having a contractor doing the spreading is that the contractor works according to a time schedule rather than at the time when the soil is trafficable. Having heavy and powerful equipment contractors can drive in the fields even when the soil is too moist for sustaining the heavy load. Further, since 1994, they plough the field shortly after harvest and sow the grass/clover in pure stand to avoid injuries to the leys of grass/clover by wheel tracks during the harvest (combiners, tractors, etc.).

This farmer declared ploughing as unavoidable in organic farming. Reasons for ploughing given by the farmers include turning of old grass fields, incorporating the large amount of straw in the carrot fields as well as combating weeds in particular grass weeds such as *Poa pratense*. Further, the ploughing depth determines the length of the carrots (a quality parameter) 25-27 cm depth.

Further, the farmer stated that compaction is the most dangerous threat to the soil. Therefore he uses low pressure tires (0.4 bar) and tries to avoid heavy traffic when the soil is not suitable for traffic. Except liming he does not use any other of the remaining actions/prescriptions listed in questionnaire 2.

In addition, the farmer stated that on many farms (but not his own) the removal of biomass for energy production would be a long term threat to soil and soil productivity. He suggested that the electricity should be produced by wind turbines placed on the highways (between lanes).

Farmer 2

This farmer remembered in particular an incident with runoff and soil erosion on 28 August 2006 where his neighbour's conventionally cultivated field, sown with winter rape, was lying just adjacent to his own rape field. On his field no erosion occurred.

Further, he mentioned that since the winter green fields were introduced by law in the late 1980ies there has been no wind erosion in the area. He stated that the occurrence of erosion was depending on weather conditions (precipitation) and the time of crop establishment. He had also noticed that since he began using no-plough tillage the soil had become more permeable (he never sees water standing on the surface) and that in case of dry conditions in spring and the beginning of summer his crops were more green than those fields nearby that was traditionally ploughed. His impression was that no-ploughed soil could hold more water than ploughed soils.

The farmer said that he took up using no-plough till as a challenge, having visited others using the practice. It was his impression that he could uphold the same yields using less man-hours, whereas the input of fossil fuel was about the same as in conventional ploughing, many more times of harrowing as well as more powerful tractor for coping with the tillage implement for tilling and sowing at the same time. He had not started no-plough till for environmental reasons but for saving time. This farmer used a combined rotor harrow and seeding machine and had mounted a deep loosing tool at the front of his tractor (10-15 cm depth).

Further, he used Fodder radish (*Raphanus sativus var. Oleiformis*) as catch crop before a spring barley crop, taking up nitrogen during autumn. In mild winters it could survive but normally it was killed by frost.

The farmer stated that he normally started tillage 5-6 days later in the spring than those using traditional tillage, in order to be sure that all parts of the fields, including low lying spots, had dried up. On the other hand fertilisation of winter wheat in spring could be done earlier at his field than at neighbours' fields because of the better internal drainage due to the no-plough tillage. Thereby his fields of winter wheat started better in the spring.

Every year ¼ of his fields was sprayed with 540 g/ha of glyphosat. Spraying was done before harvest of crops. After harvest and before sowing in autumn they harrowed the fields twice with a disc harrow times to 8 cm depth, to make a falls seed bed, promoting germination of weeds seed and spilled grain burring stubble and weeds.

In earlier days he had a contractor sowing winter wheat (using a Horsch machine), but as he said "Winter wheat is 'a piece of cake'", i.e. easy done using no-plough tillage whereas spring sown grain is more tricky, timing has to be right.

The further applies no lime on his soils and stated that pig slurry in fact caused a high pH of his soil, around 6.5-7 pH. The farmer felt that in general there was too much scrutiny in controlling farmers, e.g. they were checked whether the sizes of their fields were exactly right. He said that too many resources went into controlling. This farmer would prefer that all farmers were competing at world market terms. In addition, he did not see any possibility in effecting the political systems dealing with farming matters.

Compaction is the major long term risk on his farm.

Farmer 3

This farmer had been conducting no-plough tillage for 4 years sharing machinery with a neighbour, but stopped 3 years ago.

Further, he was beginning to have problems with grass weeds as well as problems with *Fusarium fungi*, affecting the productivity of his sows. Fusarium, he said, acted on the sows as birth control pills do on women, reducing the numbers of pregnancies. And even further having that many animals no-plough tillage was a stress factor, you can get a good crop using the plough even if you are not timing the tillage all that well.

He had seen erosion rills on sloping land in his neighbourhood, however just once on his own land. Before winter green fields became mandatory he had observed wind erosion on neighbouring more sandy fields. This farmer was not aware of problems with compaction on his land or of any other soil quality related problems.

Depending on his own need for straw for his animals he sold surplus straw at an average every second year. He did not consider a problem regarding carbon balance on soils of his farm. For the mandatory catch crop he used ryegrass sown in the winter wheat in the spring. This farmer used 3-axel slurry spreader as well as low pressure tires. In addition, the farmer stated that he limed his field every 5 years. The average field size of his farm was 30 ha.

Farmer 4

This farmer was very much aware of the problem of soil compaction. Although he did not have animals on the farm he had been using slurry from neighbours. In the past he had several times refused to have the heavy machines in his fields when the soil was too moist. Now he had an arrangement with a contractor who used a machine from a company called Vredo. This machine had 4 wheels on 2 axels and could drive in a way called dog-walk-position, which meant that each of the 4 wheels drove in its own track, whereby compaction could be minimised. In spite of this, he had observed some packing at the end of the fields which is affected the most by traffic. Slurry was always applied (incorporated) before sowing of spring barley.

Except for the minor problem of compaction the farmer did not experience any other problems of soil degradation. The farmer applied lime on the soil of his farm approximately every 5-6 years and used broad tires (twin tires) when appropriate.

Further, this farmer in the past had tried to practice deep soil loosening but it was his experience that it did not alleviate problems of compaction – rather the contrary. Consequently now he did his best to avoid compaction.

He had quite a lot of shelter belts, good for hunting. He stated that he would not engage in soil conservation tillage because he was too old for changing and wanted to use his farming equipment to the end of his days as a farmer. This farmer did not use any of the suggested methods for avoiding problems with reduced soil quality. He was aware what sanctions could be imposed upon him if he did not live up to regulations.

In addition, he had been active in the board of farmers' advisory system. Therefore he was a firm believer in influencing the politicians via the farmers union and the local representatives/politicians. He did not think that it would be possible for him as a person to affect the policy design directly and detail but indirectly by his network.

The average field size of his farm was 8-9 ha.

4.2 Suitable soil conservation measures

The size of agricultural machinery has been increasing during recent decades and is expected to continue doing so in the future, in line with the trend towards larger and fewer farms. The regulation of slurry application has induced intense traffic in early spring but harvest of sugar beets, silage maize and potatoes can involve high wheel loads at times where soils are likely to be very wet. For the southern part of Sweden, having weather conditions similar to Danish areas with sugar been growing, Arvidsson et al. (2003) calculated the probability of traffic taking place under unfavourable conditions when sugar beets were being harvested. They calculated a nearly 100 % probability of the soil being compacted in 50 cm depth when trafficking the fields between September and November, at which time most sugar beets are being harvested. Very large combine harvesters are used in Danish agriculture, carrying up to 20 tonnes on the front axle. Frequently, precipitation patterns of the late summer months induce traffic with such loads also when harvesting small grain cereals in Denmark. Spreading of slurry and taking the harvested crops from the field often involves axle loads as high as 10-12 tonnes. In particular, the compaction of deeper soil layers is of concern, as neither tillage nor biological activity (e.g. plant roots and animals) seems able to efficiently deal with the problem.

As a criterion for sustainable traffic on soil, Schjønning et al. (2006) have suggested a fixed threshold of 50 kPa vertical stress in 50 cm soil depth. As a rule of thumb for the farmers and their adviser the depth for maximum allowable stress (50 kPa) will increase approximately 8 cm for each additional tonnes of wheel load and approximately 8 cm for each doubling of the inflation pressure. Based on this, it can be calculated that currently even the best low-pressure tyres (50 kPa inflation pressure) available for use in agriculture should not be loaded with more than ~3.5 tonnes in order to keep soil deeper than 50 cm free of >50 kPa vertical stress.

Tables 9 and 10 respectively are showing which effects cropping/ tillage measures and long-term measures have on the mitigation of soil degradation problems. Reduced tillage (Table 9) is scarcely used in Denmark and the problems that could have been dealt with using this form of tillage must therefore be handled otherwise. The decline in organic matter has linkages to water erosion as well as compaction. Declining organic matter contents must therefore be handled through crop rotations involving e.g. grass leys as well as the use of organic fertilisers. The removal of biomass for energy production, as also pointed out by one of the interviewed farmers, can pose a long-term threat to the quality of our soils.

As shown in Table 9 diffuse contamination (nitrate leaching) has been dealt with using four conservation measures, one being undersown crops, to take up mineralised nitrogen during autumn and winter, and three others being restrictions on the use, amount and timing of the manure application. Laws had enforced all four.

Reduced tillage had been observed by one farmer as effective against erosion by water, however three other farmers did not consider erosion by water a problem at all.

Table 8: Typical cropping systems, their characteristics and the estimation of impacts on soil degradation problems in the case study Bjerringbro/Hvorslev, Denmark

Crop	Barley, spring – grain	Maize, Fodder – silage	Soft wheat, winter – grain	Barley, winter – grain	Grass, permanent pasture – fresh	Grass, temporary (< 4 years) – silage	Rape – grain
Production orientation	conventional	conventional	con-ventional	con-ventional	con-ventional	con-ventional	conventional
Farm type	livestock farm > 1.5 LU	livestock farm > 1.5 LU	livestock farm > 1.5 LU	livestock farm > 1.5 LU	livestock farm > 1.5 LU	livestock farm > 1.5 LU	livestock farm > 1.5 LU
Tillage type	ploughing	ploughing	ploughing	ploughing	ploughing	Ploughing	ploughing
Irrigation type	no irrigation	no irrigation	no irrigation	no irrigation	no irrigation	no irrigation	no irrigation
Other management options	Avoid heavy slurry spreading equipment in fields – use slurry buffer tank at field edge. Adjust tire pressure; reduce load; increase number a tires/ axels on slurry spreader	Avoid heavy slurry spreading equipment in fields – use slurry buffer tank at field edge. Adjust tire pressure; reduce load; increase number a tires/axels on slurry spreader					Avoid heavy slurry spreading equipment in fields – use slurry buffer tank at field edge. Adjust tire pressure; reduce load; increase number a tires/ axels on slurry spreader
Soil quality class	1, 2 and 3	1, 2 and 3	1, 2 and 3	1, 2 and 3	2	1, 2 and 3	2 and 3
Soil degrada-tion problem	Vulnerability						
Soil erosion water	low	medium	high	high	low	Low	low
Decline in or-ganic matter	medium	medium	medium	medium	low	Low	low
Compaction	high	medium	low	low	low	Low	medium

Notes:

There are three soil quality classes in the case study: class 1 means podsols (poor quality); class 2 means phaeozems (good quality) and class 3 luvisols (better quality)

In addition to these results further statements to typical cropping systems were given in the framework of questionnaire 2

Table 9: Effects of cropping/tillage soil conservation measures on soil degradation problems

	Soil degradation problem									
Measures	soil erosion water	soil erosion wind	decline in organic matter	negative carbon balance	diffuse contamination	compaction	salinisation	acidification	decrease of water reten-tion capacity	Off-site damage
Undersown crops					1					
Reduced tillage	2		2			1				
Restrictions on the max. amount of (liquid) manure application					1					1
Restrictions of manure application to a certain time period					1					1
Restrictions on the max. amount of N-fertilisation					1					1

Legend: The numbers indicate *the general effects of soil conservation measures on soil threats in the case study*, examined in questionnaire 1 with the following units: 2 = farming practice highly mitigates the threat, 1 = farming practice mitigates the threat, 0 = farming practice has no effect on threat. The grey marked cells are not relevant because this measure has no relationship to the threat.

Table 10: Effects of long term soil conservation measures on soil degradation problems

	Soil degradation problem									
Measures	soil erosion water	soil erosion wind	decline in organic matter	negative carbon balance	diffuse contamination	compaction	salinisation	acidification	decrease of water reten-tion capacity	Off-site damage
Liming						1				
Drainage management to mitigate salinisation and/or compaction						1				
Controlled traffic tramlines						1				

Legend: The numbers indicate *the general effects of soil conservation measures on soil threats in the case study*, examined in questionnaire 1 with the following units: 2 = farming practice highly mitigates the threat, 1 = farming practice mitigates the threat, 0 = farming practice has no effect on threat. The grey marked cells are not relevant because this measure has no relationship to the threat.

5 Evaluation of soil conservation measures

5.1 Fixed tracks

In order to reduce leaching of nitrate, law has prohibited nearly all spreading of animal manures in the autumn, and the majority of manure is now applied in spring. The use of heavy machinery for the spreading of slurry in spring, either before sowing of spring crops or for fertilising winter cereals and winter rape, is recognised as a threat of soil compaction by all four farmers interviewed. Three of the farmers had responded to the threat by buying their own spreading equipment, enabling them to spread their slurry at a time when the soil was dry enough to better sustain the loads exerted by the machinery. The last farmer used a machine station with a special type of spreading equipment, exerting less stress to his soil. The use of fixed driving tracks/tram lines by use of GPS was conducted by the organic farmer in his production of vegetables. Further he tried to avoid any excess passing on the field. This "solution" may however lock the farmer to a certain working distance between tracks. This may not work for all crops in a rotation and may be depending on the producers of farming implements.

As wheel tracks, in Danish as well as studies abroad, have been seen promoting or even inducing erosion this measure may be combined with the loosening, e.g. by a harrow tooth, once or whenever driving in the track. This is however not done as water erosion is not seen a problem of concern.

5.2 Reduce traffic load and impact

Avoid heavy loadings in the field when soil was moist. Useful technical measures to avoid degradation are wide tires, twin tires and buffer tanks at the edge of the field when spreading slurry. Both farmers and expert agree that this will be beneficial to the soil and the avoidance of compaction.

Another way of avoiding the heavy loading during spreading of slurry would be the use of a self driving spreader with hoses, connected via a pipeline to the slurry tank. The system resembles the way a rain gun or irrigation machine operates. Construction of the pipeline system may require that all of a farmers land is interconnected. Alternatively more farmers should join forces. This has been seen in some other area of Denmark. A benefit for society would be the reduction of traffic by heavy machines on public roads.

5.3 Shelterbelts

Wind erosion does not appear to be a problem in the area, in spite of the removal of many shelterbelts and the enlargement of fields. New shelterbelts are mainly planted for the sake of the wildlife (game hunting) rather than for shelter against the wind. As noticed by all of the farmers, winter green fields and catch crops e.g. of rye grass have acted as a protection against wind erosion.

Shelterbelts will be most effective against wind erosion when planted perpendicular to the prevailing wind direction. Against water erosions they have to block the flowing water, and therefore be along contour lines or across flow paths.

5.4 Conclusion

Farmers are obliged to use catch crops on a part of their land and further have to keep part of their land covered with a winter crop (cereals or winter rape) both aimed at reducing nitrate leaching during autumn and winter. A side effect, not planned, has been the reduction of wind erosion that used to be a problem on the sandy soils. Establishment of shelter belts used to be a prerogative on the sandy soils. Due to increase in farm size shelter belts have been removed in many places to increase field size making the use of ever bigger machinery possible. The removal of shelterbelts has apparently not caused increased problems with wind erosion, probably due to increased surface roughness by plant coverage in autumn/winter.

The farmers interviewed had their focus on soil compaction by heavy machinery, in particular during spring application of slurry. In many cases soil may be too moist to sustain the heavy traffic. To reduce this problem, three out of four farmers had purchased their own equipment allowing them to apply the slurry at a time, when the moisture of the soil was low enough to sustain the machinery whereas one, having no animals on his farm but receiving slurry from a neighbour, relied on a contractor with a special type of machine.

One farmer claimed that soil structure on his farmed has improved due to the shift to no-plough tillage, whereas another farmer (organic) said that his soil's quality increased within five years and ascribed that to many clover grass fields as well as heavy inputs of organic matter (straw).

6 Soil related actors

6.1 Actors in the farming practices arena

To own and manage a farm in Denmark a person needs to be properly trained and educated. Farmers are trained at special farming schools were they receive education – both practical and theoretical – in topics such as farm management, legislation, economics, etc. Further, during the time of training students have to work in periods at farms (called practice). All of the farmers interviewed in the study area had gone through similar practical and theoretical training before starting as farmers themselves.

The farmers interviewed in the area may not representatively reflect all of the farmers, neither in the study area nor in the country as whole. However, as they were they not randomly selected most of the important farming types/forms in Denmark were represented i.e. conventional pig, dairy and arable production as well as an organic farmer having both dairy and vegetable production.

Table 11: Number of Danish farms cultivating and leasing land in 20075

Farm size (ha)	Number of farms leasing land (N)	Number of farms (N)	Leased area (ha)	Total cultivated area (ha)	Area cultivated by size of farm (%)	Average farm size, owned and leased land (ha)
< 10.0	1,503	10,460	5,066	66,136	2.5	6.3
10.0-19.9	2,403	8,427	13,847	121,456	4.6	14.4
20.0-29.9	1,885	4,826	16,671	118,643	4.5	24.6
30.0-49.9	3,097	5,634	38,271	218,372	8.2	38.8
50.0-74.9	2,978	4,189	55,944	257,375	9.7	61.4
75.0-99.9	2,383	2,904	61,276	252,349	9.5	86.9
100.0-199.9	5,056	5,560	246,218	777,341	29.2	139.8
> 200.0	2,443	2,617	343,435	851,088	32.0	325.2
Total	**21,748**	**44,617**	**780,728**	**2,662,760**	**2.5**	**59.7**

Source: Statistics Denmark (http://www.statistikbanken.dk/statbank5a/default.asp?w=1280)

The number of Danish farms cultivating and leasing land in relation to the average farm size is shown in Table 11. Table 12 contains the farming types and acreage across the country. When comparing average farm sizes of Denmark with the areas cultivated by the farmers interviewed it can be seen, that three out of four farms selected in the case study area represented large farms (5.9 % of the farms that cultivate 32.0 % of the total UAA).

In 2006 there were a total of 47,385 farms in Denmark and the UAA was 2,710,507 ha, out of which 130,667 ha were cultivated organically. Table 12 shows that by 2007 the number of farms had been reduced by a further 2,768.

Table 12: Farming types and acreage in Denmark 2007

	Number of farms (N)	Cultivated area (ha)
Specialised in grain production	13,244	549,969
Specialised in dairy farming	4,451	487,126
Specialised in pig farming	2,276	258,609
All farms	**44,618**	**2,662,761**

Source: Statistics Denmark (http://www.statistikbanken.dk/statbank5a/default.asp?w=1280)

6.1.1 Description of characteristics and attitudes

Farmers interviewed in the study area all owned their farm. A description of the farms is given in Table 13.

[5] There are no data available concerning the case study area.

Table 13: Farm type and cultivation on the selected farms in the case study area

	Farmer 1	Farmer 2	Farmer 3	Farmer 4
Affiliation/position of the interviewee	Owner, using advisors as sparing partners	Owner, using advisors as sparing partners	Owner, using advisors as sparing partners	Owner, using advisors as sparing partners
Supplement information affecting decisions making	Farming magazines, advisors/ consultants, farmers groups	Farming magazines, advisors/ consultants, farmers groups	Farming magazines, advisors/ consultants, farmers groups	Farming magazines, advisors/ consultants, farmers groups
Cultivation form	Organic	Conventional	Conventional	Conventional
Tillage type	Ploughing	No-plough tillage since 7 years.	Ploughing (gave up no-plough tillage 5 years ago)	Ploughing
Training	Farmer	Farmer	Farmer	Farmer
Farm type	Dairy: arable (vegetables)	Livestock: pigs, 1000 sows 50 % slaughter pigs, 50 % weaners for sale	Livestock: pigs, 700 sows 33 % slaughter pigs + 67 % weaners for sale	Arable: pig slurry from neighbour
Owned area (in ha)	100	312	260	57
Leased area (in ha)	200	0	20	15
UUA total (in ha)	300	312	280	72
Drainage	No	Yes	Yes	No
Crops				
S. Barley (in %)	7	25	11	35
W. Rape (in %)		25	11	
W. Wheat (in %)	9	50	39	40
W. Barley (in %)			39	
Turf grass seeds (in %)				25
Maize (in %)	7			
Grass and clover (in %)	42			
Leek (in %)	9			
Carrots (in %)	17			
Broccoli (in %)	9			

The farmers make the decisions about farm management and consult with their advisors. One farmer having his own primary focus on the production of pigs had given large influence to a hired man on the farm on how and when to conduct the various soil management operations.

6.1.2 Factors influencing adoption of soil conservation measures

Farmers follow the rules and regulations from the national parliament and the EU with the sole purpose of obtaining subsidies e.g. Cross Compliance, mandatory winter green crops, catch crops, stocking densities, regulations on fertiliser application regarding timing and amounts. There are no rules regarding crop rotation or restrictions on which crops to grow where.

Farmers themselves have realised that there may be a risk of soil compaction. They have become aware of this risk through participation in meetings, reading agricultural literature and information from advisors. Farmers take some action when it is commanded and when they are seeing an economic benefit.

6.2 Actors in the policy design and implementation arena

6.2.1 Governmental organisations

The most important governmental actors affecting policy design are the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment. Local authorities are represented by the Local Governments Association in the policy making process. Regional authorities are responsible for the enforcement of environmental legislation whereas the Ministry of Food, Agriculture and Fisheries is the primary actor involved in the delivery of relevant payments and monitoring of compliance under the common agricultural policy in the EU.

The official Danish position on soil conservation issues is documented in a commentary to the proposed EU Soil Framework Directive (Danish Environmental Protection Agency, 2006). The document states that problems of landslides and salinisation do not exist in Denmark. It also states that erosion, loss of organic material and soil compaction do not have dramatic dimensions in Denmark. The Ministry of Food, Agriculture and Fisheries concludes that it is difficult to assess if there are areas in Denmark which should be categorised as risk areas in this context. It is presumed that the implementation of this part of the Soil Directive would not require any changes in Danish legislation nor would it have any major economic consequences (ibid.).

The interviews with officials from the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment have not revealed any major differences in the positions regarding soil degradation problems in Denmark. It is generally agreed that protecting soil from pollution is a major objective, whereas protection of soil against other threats is not.

6.2.2 Civil society and non-governmental organisations

A number of non-governmental organisations also influence the agenda of agri-environmental policy, the most important being Danish farmers' organisations, the Danish Agricultural Advisory Service and the NGOs such as the Danish Conservation Association and the Ecological Council. Not surprisingly, farmers' organisations usually try to tone down agri-environmental problems while other NGOs exert permanent pressure on political decision makers to implement stricter regulation. Neither farmers' organisations nor the NGOs have focussed on soil conservation as a major issue. This holds for all levels of government: national, regional and local.

The Danish Agricultural Council has expressed the view that there is no need for an EU Soil Protection Directive (Danish Ministry of the Environment, 2007). Environmental NGOs have not focussed specifically on soil conservation issues. However, the NGOs have for a long period demanded a strengthening of agri-environmental policies in general to protect the aquatic environment and to enhance biodiversity. For example, the Ecological Council advocates a strengthening of regulation implemented primarily to protect the aquatic environment from agricultural pollution. As outlined in chapter 7 of this report, a number of these agri-environment measures will also have a positive impact on soil conservation.

Universities provide analyses and different types of advice to ministries and agencies involved in the policy making process. Concerning agri-environmental policy the most important actors at the university level are the Faculty of Agricultural Sciences, University of Aarhus and the Faculty of Life Sciences, University of Copenhagen. Soil conservation issues are studied at both institutions.

Universities in Denmark do not have agricultural extension services. The agricultural advisory sector is organised mainly by the agricultural organisations, with some financial support from the Government. The advisory service is aware of the soil compaction and carbon depletion issues and farmers' magazines have occasionally mentioned research results pointing to these problems.

6.2.3 Resources, capacities and networks

Before new legislation is passed technical and economic issues are usually assessed by committees consisting of experts (university researchers), stakeholders and civil servants from the relevant ministries and agencies. The experts are primarily from the Faculty of Agricultural Sciences, University of Aarhus, the Faculty of Life Sciences, University of Copenhagen and the National Environmental Research Institute, University of Aarhus. Usually environmental NGOs and agricultural organisations are also represented in these committees.

A number of studies conducted by the Faculty of Agricultural Sciences indicate that there are soil degradation problems in Denmark, especially related to soil compaction and carbon depletion (Munkholm and Schjønning 2004; Schjønning and Rasmussen 1994; Schjønning et al. 2002; Schjønning et al. 2004; Schjønning et al. 2007) The case study has revealed that officials from the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment are familiar with these result, but no policy action has been taken so far. Neither have there been any indications that such initiatives are under way.

Assessing the influence of the environmental NGOs and the agricultural organisations is difficult. When the first agri-environmental programmes were implemented in Denmark in the mid 1980s there is no doubt that NGOs had a significant role in the policy making process, especially the Danish Conservation Association. Subsequently, the agricultural organisations managed to slow down the process and to weaken the measures implemented to protect the environment. Both parties have tended to claim that their arguments are overlooked and overruled in the policy making process. Neither the NGOs nor the agricultural organisations have placed any particular focus on soil conservation issues.

At present it seems that NGOs as well as agriculture have in fact lost influence on the policy making process whereas the role of researchers and government officials has been strengthened. At least this could be indicated by the absence of NGOs and agricultural organisations in some recent governmental committee work on agri-environmental problems.

6.3 Conclusions

Farmers follow the rules and regulations from the national parliament and the EU with the purpose of obtaining subsidies and avoiding penalties under the Cross Compliance rules and other regulations. There are no rules regarding crop rotation or restrictions on which crops to grow where. Farmers themselves have realised that there may be a danger of soil compaction, primarily based on information from agricultural literature and advisors.

The most important non-governmental organisations influencing agri-environmental policy making are Danish farmers' organisations and environmental NGOs such as the Danish Conservation Association and the Ecological Council. Neither farmers' organisations nor the NGOs have focussed on soil conservation as a major issue. There are indications that the influence of non-governmental organisations has been somewhat weakened recently.

The most important governmental actors affecting policy design are the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment. The case study has not revealed any major differences in the positions of the two ministries regarding soil conservation issues in Denmark. It is generally agreed that erosion and salinisation are of no major concern in Denmark. On the other hand, soil compaction and the carbon balance are noted as problems worth considering. University research clearly plays a role in this context. Still, the case study has not revealed any concrete plans to take policy action to address the soil compaction and carbon balance issues.

7 Policies for soil conservation

There is no specific Danish legislation or policy addressing soil protection on arable land and there are no Cross Compliance rules specifically aimed at soil conservation or protection of soil quality. Nor are these issues addressed in Codes of Good Agricultural Practices or the like. Due to this there is no relevance to fill out individual fiches. However the policy measures that indirectly influence soil conservation are discussed below. A classification of existing policies which may affect soil conservation is attempted in Table 14.

Criteria for the use of agricultural land in Denmark are given in the Act relating to management of agricultural land (Act No. 434 of 2004). In general terms the Act states that the use of agricultural land must be sustainable and conducted in such a way that a good basis for agricultural production is maintained alongside with the preservation of environmental values and landscape amenities. The primary focus is on the specific usages permitted and restrictions regarding the use of plants and vegetation cover. Particular emphasis is placed on land owners' duty to keep agricultural land free of trees and shrubs. There are no concrete requirements regarding soil conservation in terms of: soil erosion, decline in organic matter, soil compaction, decline in soil biodiversity, salinisation, floods and landslides.

A number of other laws and provisions affect soil protection as a by-product the most significant being regulation of the use of fertiliser and plant cover (Consolidated Act No 757 of 29 June 2006 on the use of fertiliser by agriculture and on plant cover). According to this regulation, agricultural enterprises must register in the Registry for Fertiliser Accounts in order to purchase fertiliser without paying a fee. Consumption of nitrogen must not exceed the fixed nitrogen quota calculated and allotted yearly for the enterprise. In addition, agricultural enterprises must each year establish a spring or autumn crop in agricultural fields in order to enhance normal nitrate uptake. The area with autumn crops must cover at least 6 % of the dedicated autumn crop area for the farm. The crop must not be ploughed down or otherwise destructed before the 20th October.

The primary purpose of the Act on shelterbelts and support for planting of shelterbelts (Act No. 466 of 2001) is to reduce wind erosion. There is no data available indicating to what extent this legislation has led to planting of shelterbelts in the study area.

The important provisions affecting soil conservation are found in regulation aiming at the protection of the aquatic environment. A political agreement on Aquatic Action Plan III 2005-2015 stipulates that a total of 50,000 hectares of buffer zones must be established, primarily to reduce phosphorous discharges to the aquatic environment (Danish Government, 2004). The total of 50,000 hectares comprises 30,000 hectares of 10-meter crop-free buffer zones along rivers and lakes to be established before 2009 and a further 20,000 hectares before 2015. The Aquatic Action Plan III also strengthens the demands regarding plant cover. Animal farms with more than 0.8 livestock units per hectare must establish catch crops on 10 per cent of the arable area. This demand will be increased to 14 per cent in 2009 (op. cit.). The primary purpose is to reduce nitrate leaching, but catch crops also reduce soil erosion and build up organic matter in the soil.

Soil contamination, on the other hand, is covered by the Soil Pollution Act. It is the purpose of this Act to prevent and limit pollution of the soil. According to the Danish Government this legislation covers for the most part the requirements in the proposed EU Soil Framework Directive as far as soil pollution is concerned (Danish Ministry of the Environment, 2007).

A number of agri-environment measures under the Danish Rural Development Programme also contribute to soil conservation:

- Conversion to organic farming (support is granted for conversion to organic farming for cultivated agricultural areas during a 5-year commitment period)
- Extensive production on agricultural land (support is granted for pesticide free farming during a 5-year commitment period. Support is paid for cultivated agricultural areas only)
- Establishment and management of set-aside border strips (area payments for five years for replacement and special conservation of set-aside areas. The set-aside must be placed on border strips adjacent to lakes and watercourses and will reduce soil erosion to the lake or watercourse)
- Establishment of wetlands (support is offered for establishment and sustainable management of wetlands on farm land)
- Establishment of landscape and biotope-improving vegetation, including shelter plants.

In connection with the proposed Soil Framework Directive the Danish Government has also considered the soil conservation issues related to soil erosion, decline in organic matter, soil compaction, salinisation, floods and landslides. It was concluded that soil erosion, decline in organic matter and soil compaction are problems of minor importance, whereas salinisation and landslides do not constitute a problem in Denmark (op. cit.). Therefore, the implementation of the proposed Soil Framework Directive would not necessitate changes in existing Danish legislation (op. cit.). In other words, the absence of specific provisions regarding soil conservation in Danish legislation is not considered a shortcoming by the Government.

Table 14: Classification of policy measures in Bjerringbro and Hvorslev (DK).

Type of Policy Mechanism/ Mode of governance	Practical classification Nature of the Policy Objective			Policy relationship to agriculture	Geographical level	Analytical classification – Channels of Impact Primary (1) and Secondary (2) impacts. Y = Yes, N = No		
	Soil conservation is the **primary objective** of a policy measure	Soil conservation is the **secondary objective** of a policy measure	Soil conservation is a **By-product**	Agricultural (AG) or non Agricultural (NAG) focused policy	European (E), national (N), regional (R) or local (L) measure, and policy reference	Developing new/altering existing rules (institutions)	Developing and/or altering governance structures/ implementation approaches	Directly impacting on farmer behaviour/ decision making/ factor allocation and management practices
Command and Control				AG	E – Nitrate Directive			
			Buffer zones, plant cover		N – Aquatic Action Plan III 2005-2015			
			Water Body Management	NAG	E – Water Framework Directive			
Incentive based measures/economic instruments			Agri-environmental schemes	AG	E – but varies at N			
			Wetlands in special sensitive agricultural areas	AG	N – Establishment and management of wetlands			
Moral Suasion Initiatives, i.e. it has a normative dimension that farmers should protect soils								
Information and capacity building measures, i.e. guidance, advisory measures and farmer support initiatives							Y	
							Y	

8 Conclusions

Soil erosion (water and wind) are not seen as significant problems in Denmark whereas soil compaction and decline in soil organic matter cause some concern. None of the farmers considered erosion by wind and water as a problem. They all had knowledge of the potential threat to their land which could be damaged by compaction due to heavy traffic. The farmers saw that particular in connection with spreading of manures in the spring when soil was moist. All four farmers had reacted accordingly, trying to avoid traffic as much as possible when the soil was most vulnerable and using low pressure tires. One farmer (no 1) stated the organic matter depletion could be threatening the soil in the longer run, when taking out biomass for energy production.

According to the Danish Government, landslides, salinisation and erosion are either non-existing or insignificant problems in Denmark. Governmental agencies acknowledge that loss of organic matter and soil compaction may constitute a problem – at least in the long run. Nevertheless, the Government holds the position that the implementation of this part of the European Soil Framework Directive would not require any changes in Danish legislation nor would it have any major economic consequences.

None of the interviewed officials felt that there was a basis for rating policy measures with respect to their impact on soil conservation. Neither did they suggest any policy measures to address the (alleged) problems with declining soil organic matter and soil compaction. The interviewed NGO representative suggested a strengthening of existing agri-environmental regulations, which would increase soil protection as a by-product.

It can be concluded, therefore, that such phenomena as landslides, salinisation and soil erosion are not considered as problems of importance in Denmark. In this context there are no significant differences between positions of the official side (the Government and governmental agencies) on the one hand and NGOs or agricultural organisations on the other. However, scientific investigations indicate that there are (potential) problems related to soil compaction end organic matter depletion. Governmental agencies as well as farmers acknowledge that there are reasons to be concerned about these threats.

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List of interviews

Interview Date	Interviewee (affiliation/position)	Type of interview
14/7-08	Farmer 1	face-to-face
14/7-08	Farmer 2	face-to-face
15/07-08	Farmer 3	face-to-face
15/07-08	Farmer 3	face-to-face
August 2008	Representative of The Ecological Council	
August 2008	Representative of the Ministry of Food, Agriculture and Fisheries	filled out questionnaire individually
August 2008	Representative of the Ministry of Environment	

Annexes

Annex 1: Overview of the results of Questionnaire 1

Main farm types	arable, livestock
Main crops	barley, maize (fodder), soft wheat, grass, rape
Livestock	bovine (race: Holstein-Friesian), pigs (crossong races e.g. Duroch/Yorkshire/Danish landrace)
Main production orientation	conventional
Average field size	4 ha
Irrigation methods	none
Source of irrigation water	n/a
Usual salt content of irrigation water	n/a
Drainage systems	tube systems
Existing grass strips	yes
Separation of fields by hedges	no
Main soil degradation problems	soil erosion, decline in organic matter, compaction
Applied soil conservation measures (cropping/ tillage measures)	undersown crops, reduced tillage, restrictions on the max. amount of (liquid) manure application, restrictions of manure application to a certain time period, restrictions on the max. amount of N-fertilisation
Applied soil conservation measures (long term measures)	liming, drainage management to mitigate salinisation and/or compaction, controlled traffic tramlines

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Abstract

This Technical Note 'Case Study – Denmark' is part of a series of case studies within the ‘Sustainable Agriculture and Soil Conservation’ (SoCo) project. Ten case studies were carried out in Belgium, Bulgaria, the Czech Republic, Denmark, France, Germany, Greece, Italy, Spain and the United Kingdom between spring and summer 2008. The selection of case study areas was designed to capture differences in soil degradation processes, soil types, climatic conditions, farm structures and farming practices, institutional settings and policy priorities. A harmonised methodological approach was pursued in order to gather insights from a range of contrasting conditions over a geographically diverse area. The case studies were carried out by local experts to reflect the specificities of the selected case studies.

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